**Robotic-Assisted versus Video-Assisted Thoracoscopic Lobectomy: Short-Term Results
of a Randomized Clinical Trial (RVlob Trial)**

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Running Head: Robotic versus video-assisted lobectomy

Mini-Abstract

This single-center, open-labeled, parallel-arm randomized clinical trial (RVlob trial) compared the efficacy of robotic-assisted lobectomy and video-assisted lobectomy in treating non-small cell lung cancer. Both approaches are safe and feasible. Robotic-assisted lobectomy achieved similar perioperative outcomes, together with a higher lymph node yield. Follow-up for long-term survival is in progress.

Structured Abstract

Objective: To determine whether robotic-assisted lobectomy (RAL) affects perioperative outcomes and long-term efficacy in non-small cell lung cancer (NSCLC) patients, compared with traditional video-assisted lobectomy (VAL).

Summary Background Data: RAL is a promising treatment for NSCLC. However, its efficacy has not been fully evaluated.

Methods: A single-center, open-labeled prospective randomized clinical trial was launched in May 2017 to compare the efficacy of RAL and VAL. By May 2020, 320 patients were enrolled. The perioperative results of RAL and VAL were compared.

Results: The 320 enrolled patients were randomly assigned to the RAL group (n=157) and the VAL group (n=163). Perioperative outcomes were comparable between the two groups, including the length of hospital stay ($P=0.76$) and the rate of postoperative complications ($P=0.45$). No perioperative mortality occurred in either group. The total amount of chest tube drainage (830 ml [IQR, 550-1130 ml] vs. 685 ml [IQR, 367.5-1160 ml], $P=0.007$) and hospitalization costs (\$12821 [IQR, \$12145-\$13924] vs. \$8009 [IQR, \$7014-\$9003], $P<0.001$)

were significantly higher in the RAL group. RAL group had a significantly higher number of lymph nodes (LNs) harvested (11 [IQR, 8-15] vs. 10 [IQR, 8-13], $P=0.02$), higher number of N1 LNs (6 [IQR, 4-8] vs. 5 [IQR, 3-7], $P=0.005$), and more LN stations examined (6 [IQR, 5-7] vs. 5 [IQR, 4-6], $P<0.001$).

Conclusions: Both RAL and VAL are safe and feasible for the treatment of NSCLC. RAL achieved similar perioperative outcomes, together with higher LN yield. Further follow-up investigations are required to evaluate the long-term efficacy of RAL. (ClinicalTrials.gov identifier: NCT03134534)

Key Words: Non-small cell lung cancer, Robotic-assisted lobectomy, Video-assisted lobectomy, Perioperative outcome, Randomized controlled trial.

INTRODUCTION

Lobectomy is the mainstay of surgical management for patients with early-stage non-small cell lung cancer (NSCLC). It can be performed using either an open thoracotomy or minimally invasive surgical approach. Compared with conventional open surgery, minimally invasive lobectomy has been well demonstrated to be associated with an improved rate of postoperative complications, a shorter hospital stay, less surgical pain, and possibly better long-term survival^{1,2}. Minimally invasive techniques for lobectomy include video-assisted lobectomy (VAL) and robotic-assisted lobectomy (RAL).

Since the first robotic-assisted surgery was performed in 1985³, different robotic-assisted systems have been used for various surgical procedures, such as general laparoscopic surgery, urological procedures, and mitral valve repair⁴. In 2002, Melfi reported the first cases involving RAL⁵, and since then, the use of robotic assisted surgery has been widely adopted to other aspects of thoracic surgery^{6,7}. Compared with video-assisted surgery, the robotic-assisted system provides a three-dimensional, high-definition view, better maneuverability, and improved dexterity. Despite the recent increase in the popularity of robotic-assisted surgery, its role and potential advantages in thoracic surgery have not been well defined⁸. Several studies have demonstrated that robotic surgery provides similar perioperative outcomes and long-term survival compared to VAL. Other studies have shown RAL to have potential advantages over VAL in terms of lymph node (LN) dissection, the rate of postoperative complications, and the duration of hospital stay⁹⁻¹⁴.

A number of retrospective studies and meta-analyses comparing RAL and VAL have been published; however, the results have been inconsistent^{9-11,15}, and there continues to be a lack of prospective evidence. For these reasons, we conducted a single-center, open-labeled, prospective randomized controlled trial (RCT) to compare the short-term outcomes and long-term survival after RAL and VAL.

METHODS

Trial Design

This study was a single-center, open-labeled, parallel-arm, non-inferiority RCT (ClinicalTrials.gov number, NCT03134534), which was reviewed and approved by the ethics committee of Ruijin Hospital, Shanghai Jiaotong University School of Medicine (approval

number, 2017-58). All patients signed an informed consent form after personal counseling by an independent research coordinator.

Patients

Patients with pulmonary masses or nodules who were identified as suitable for minimally invasive lobectomy were included in this study. Eligible patients were 18 to 80 years old, with satisfactory preoperative laboratory testing, adequate pulmonary function and an American Society of Anesthesiologists score of I to III. Patients with pathologically confirmed pulmonary tumors other than NSCLC, current or former comorbidity with other malignant tumors, or pleural dissemination detected during surgery, along with those who had received chemotherapy, radiotherapy, or targeted therapy for any malignancies, were excluded.

Intraoperative exclusion criteria included 1) pathological diagnosis other than NSCLC on intraoperative frozen section examination; 2) pleural dissemination detected during surgery; and 3) intraoperative change of surgical plan. If any of these findings were discovered, patients were further excluded, as illustrated in Figure 1. Intraoperative change of surgical plan was defined as inappropriateness for minimally invasive lobectomy based on intraoperative exploration, such as sub-lobar resection for a small lesion or extensive lung resection for a massive tumor.

Randomization

Eligible patients were randomly assigned to undergo either RAL or VAL at a ratio of 1:1. Randomization was conducted with a computer-generated random numbers table. Assignments were sealed in opaque envelopes, which were opened by the surgeons at the time of the operation.

Surgery and Postoperative Management

All patients underwent general anesthesia with double-lumen endotracheal intubation. A da Vinci S/Si surgical robot (Intuitive Surgical, Inc, Santa Clara, CA) was used to perform RAL. Five ports were placed in the following positions: a 12-mm camera port was placed in the 8th intercostal space (ICS) at the mid-axillary line; three 8-mm working ports were placed separately in the 5th ICS at the anterior axillary line (#1 arm), the 8th ICS at the posterior axillary line (#2 arm), and the 8th ICS at 2 cm lateral to the spine (#3 arm). Finally, the auxiliary port was placed in the 8th ICS between the camera port and the anterior port (Figure 2A).

VAL was performed through a 4-cm incision, which was placed in the 5th ICS at the anterior axillary line and covered with a protective sleeve (Figure 2B). When necessary, an additional auxiliary port was placed in the 7th or 8th ICS at the mid-axillary line. All surgical instruments were inserted through the incision without spreading the ribs.

Appropriate N1 and N2 LN stations were dissected for each patient, in accordance with the NCCN guidelines for NSCLC¹⁶. All surgeries were performed by the same surgical group headed by one experienced surgeon (H.L.), who had performed more than 100 procedures by each approach before initiation of this study.

Enhanced recovery after surgery was routinely implemented for each group as previously reported, including smoking cessation, breathing training, analgesia, early postoperative activities, early postoperative extubation, *etc.*¹⁷. Rehabilitation therapists were involved throughout the process of postoperative recovery for each patient. Patient-controlled analgesia and oral non-steroidal anti-inflammatory drugs were given routinely for postoperative

analgesia in both groups. Intravenous non-steroidal anti-inflammatory drugs, meperidine and tramadol were occasionally used as extra-analgetic, if necessary. The analgesia regimen was identical in both groups.

Outcomes

The primary endpoints were the 3-year overall survival (OS) rate and the extent of LN dissection. The 3-year OS rate was defined as the percentage of patients who were still alive 3 years after randomization. LN dissection outcomes included overall LN count, the number of stations dissected, and the number of LNs in each station. The main secondary endpoints were 3-year disease-free survival, the R0 resection rate, duration of surgery, intraoperative blood loss, the conversion rate, postoperative hospital stay, the incidence of postoperative adverse events, and medical costs. Postoperative complications were evaluated based on Clavien-Dindo Classification¹⁸. Prolonged air leak (PAL) was defined as a persistent air leak requiring chest tube drainage for greater than 5 days after surgery. Postoperative pain scores were evaluated and recorded using a visual analogue scale¹⁹. Total hospitalization cost was composed of direct and indirect costs. Direct cost was the cost of items used directly in the care of patient. Indirect cost was defined as additional costs of hospitalization and surgery, which was comprised of overhead costs and amortization of surgical equipment, including the purchase and maintenance of the surgical platforms²⁰. Smoking index (number of cigarettes smoked per day * years of tobacco use) was used to evaluate the smoking status of the patient²¹.

Adjuvant therapy was arranged for patients in accordance with the NCCN guidelines for NSCLC¹⁶. Postoperative follow-up was conducted every 6 months until patient death or the completion of the study.

Statistical Analysis

Based on our previous clinical observations and review of the current literature, 3-year OS after RAL was expected to be 81.5%, and 3-year OS in the VAL group was assumed to be 74%^{13,22}. A sample size of 136 patients per group was needed to ensure an 80% power with a 5% non-inferiority margin and a significance level of 5%. Regarding the other primary endpoint, 138 patients per group were needed based on the assumption of one more LN dissected in the RAL group with a standard deviation of 5^{9,14,23,24} and a non-inferiority margin of 0.5 at the same significance level and power. The final sample size was increased to 150 patients per group to compensate for a 10% loss to follow-up.

All the statistical analyses were performed using R (version 3.5.3, R Foundation for Statistical Computing, Vienna, Austria). For categorical variables, Pearson's Chi-squared test or Fisher's exact test was used to make comparisons between the two groups. Continuous variables which were normally distributed were presented as mean $\pm$ standard deviation (SD), and Student's *t*-test was used for comparison. In cases of non-compliance, continuous variables were presented as median (interquartile range [IQR]) and compared by Wilcoxon rank-sum test between the groups. The test level between the two groups was set at $\alpha=0.05$ (bilateral), and differences with $P<0.05$ were considered to be statistically significant. Subgroup analyses were performed for the primary endpoint of LN dissection and presented as a forest plot.

RESULTS

Baseline Characteristics and Pathological Outcomes

Between May 2017 and May 2020, 381 patients were evaluated, and 363 were enrolled for randomization. Forty-three patients were further excluded before or during surgery due to withdrawal of consent (10/43, 23.3%), pathological result other than NSCLC on intraoperative frozen section (28/43, 65.1%) and intraoperative change in the surgical plan (5/43, 11.6%, mostly changed to segmentectomy). Ultimately, 320 patients were enrolled in this study and were randomly assigned to the RAL (n=157) or VAL group (n=163) (Figure 1). Of the 320 patients enrolled, the median age was 61.5 years. There were 81 males (51.6%) in the RAL group and 76 males (46.6%) in the VAL group. Baseline characteristics were balanced between the groups (see Table, Supplemental Digital Content 1, which shows the patient characteristics in each group, <http://links.lww.com/SLA/D129>), including body mass index (BMI), Eastern Cooperative Oncology Group performance score, percent forced expiratory volume in 1 second (%FEV1), percent diffusing capacity of the lung for carbon monoxide (%DLCO), smoking history, tumor location, clinical TNM stage, and history of comorbidities. Five patients with surgically resectable clinical stage T3 and T4 tumors were also included. No conversion to thoracotomy was observed due to advanced tumor stage. Most of the enrolled patients had adenocarcinoma (252/320, 78.8%). The pathological outcomes of the patients are summarized in Table 1. The majority of tumors in both groups were pathological stage IA (122/157, 77.7% in the RAL group and 118/163, 72.4% in the VAL group). The pathological TNM stage was comparable between the two groups.

Perioperative Outcomes

Table 2 presents a comparison of perioperative outcomes between the two groups. Seven patients (4.5%) in the RAL group and 9 patients in the VAL group (5.5%) underwent intraoperative conversion to thoracotomy ($P=0.86$). The main reasons for conversion were intraoperative hemorrhage (6/16, 37.5%, 4 [2.5%] in the RAL group vs. 2 [1.2%] in the VAL group, $P=0.44$), difficulty dissecting sclerotic LNs (4/16, 25.0%) and severe pleural adhesions (4/16, 25.0%). In the VAL group, an additional auxiliary port was placed for 3 patients (3/163, 1.8%).

There were no 30-day mortality in either group. No significant differences were found in operative time (110 min [IQR, 95-140 min] vs. 120 min [97.5-150 min], $P=0.25$), postoperative hospital stay (4 days [IQR, 4-5 days] vs. 5 days [IQR, 4-5 days], $P=0.76$), intraoperative blood transfusion rate (1.9% vs. 1.2%, $P=0.68$), duration of chest tube placement (3 days [IQR, 2-4 days] vs. 3 days [IQR, 2-4 days], $P=0.97$), visual analogue pain score on postoperative day 1 to day 3 ($P>0.05$), duration of extra analgetic (0 day [IQR, 0-1 day] vs. 0 day [IQR, 0-1 day], $P=0.11$), or the rate of postoperative complications (14.6% vs. 18.4%, $P=0.45$). The rate of complications by severity (grade I-II and grade III-IV) were also comparable between groups. The most frequent complications were pleural effusion, air leak and pneumonia. Nine patients in the RAL group and 10 in the VAL group experienced PAL. Of these patients, the median duration of air leak was 7 days in the RAL group, and 10.5 days in the VAL group respectively ($P=0.10$). Intraoperative blood loss was strictly controlled in both groups and was statistically lower in the RAL group than in the VAL group (100 ml [IQR, 50-100 ml] vs. 100 ml [IQR, 50-150 ml], $P=0.04$). The total amount of chest tube

drainage (830 ml [IQR, 550-1130 ml] vs. 685 ml [IQR, 367.5-1160 ml], $P=0.007$) was significantly higher for patients who underwent RAL.

The total hospitalization cost (\$12821 [IQR, \$12145-\$13924] vs. \$8009 [IQR, \$7014-\$9003], $P<0.001$) and indirect cost (\$5197 [IQR, \$5197-\$5205] vs. \$453 [IQR, \$445-\$453], $P<0.001$) were significantly higher in the RAL group. However, no significant difference in the direct cost was observed between groups (\$7624 [IQR, \$6491-\$8708] vs. \$7572 [IQR, \$6574-\$8550], $P=0.15$).

Results of LN Dissection

Total number of LNs dissected was higher with RAL than with VAL (11 [IQR, 8-15] vs. 10 [IQR, 8-13], $P=0.02$), as was the total number of LN stations examined (6 [IQR, 5-7] vs. 5 [IQR, 4-6], $P<0.001$) (Table 3). Additionally, a higher number of LNs in N1 stations were dissected during RAL (6 [IQR, 4-8] vs. 5 [IQR, 3-7], $P=0.005$), while the number of N2 LNs were not different (5 [IQR, 4-8] in the RAL group vs. 5 [IQR, 3-7] in the VAL group, $P=0.19$). No differences were observed in the nodal upstaging rate (7.6% in the RAL group vs. 12.3% in the VAL group, $P=0.23$) between RAL and VAL or across different subgroups ($P>0.05$). According to subgroup analyses, favorable LN dissection results were observed in the RAL group (mean difference >0) across 10 studied subgroups, except a few subgroups with extremely limited sample size (Figure 3).

DISCUSSION

The safety and oncological efficacy of VAL in the treatment of NSCLC have been well established^{25,26}. Consistent with VAL, RAL has been demonstrated to achieve superior surgical outcomes to conventional open surgery²⁷. Long-term survival after RAL has also

been confirmed in recent studies^{12,13}. However, no previous study has provided prospective evidence on outcomes after RAL. Currently there are a few ongoing prospective clinical trials on RAL, focusing mainly on short-term outcomes (NCT03152071, NCT02617186, NCT02804893, NCT02292914). Our study is the first prospective RCT to compare both short-term outcomes and long-term survival between VAL and RAL. The short-term results of our study showed that RAL had comparable perioperative outcomes to VAL with a higher number of LNs resected. The primary outcome measure of 3-year OS has not yet been reached and will be presented in a future report.

The assessment of LNs is of critical importance in minimally invasive lobectomy for NSCLC. A number of published studies have evaluated the capacity of robotic systems in LN resection and have produced conflicting results. Nelson *et al.* recently reported that compared with VAL, RAL was associated with increased nodal stations examined and a higher number of LNs harvested²⁸. This conclusion has also been verified by many other retrospective studies^{23,29,30}. However, according to Kneuert *et al.*, the nodal harvesting capacity was comparable between the two techniques¹⁵. Our study demonstrated that RAL retrieved a higher number of LNs, especially for N1 LNs, and examined more LN stations than VAL, while the number of N2 LNs retrieved was not different. Superiority of nodal dissection was also consistent across subgroups, which showed no impact of patient characteristics on LN assessment (Figure 3). This could be attributed to the three-dimensional, high-definition visualization, better maneuverability, and improved dexterity provided by the robotic-assisted system, which endowed surgeon with better dissection capabilities for LNs around vessels and bronchi. However, the potential survival benefit derived from an extra LN and nodal

station retrieved in the RAL group may be negligible. According to a recent study by Dezube *et al.* which investigated the correlation between the number of LNs removed and long-term survival based on the National Cancer Database, the optimal number of LNs removed was 4 for lobectomy, and additional LN sampling conferred no survival benefit³¹. The insignificant correlation between a marginally improved number of LNs and survival has also been reported by Hennon *et al.*³². Further follow-up of our study is needed to assess any clinical relevance between the improved LN dissection in the RAL group and long-term survival. In this study, even with more LNs examined, no increase was observed in the rate of nodal upstaging with RAL. Several studies have reported that the incidence of upstaging after RAL ranged from 10.9% to 16.4%^{15,23,32-34}, which is marginally higher than our result (7.6%), while the upstaging rate in the VAL group (12.3%) is consistent with most previous publications ranging around 12%^{15,23,32,35}. The majority of enrolled patients had early-stage disease, which may explain the insignificant difference in upstaging rates between the groups. Previous studies have reported conflicting results regarding nodal upstaging^{15,32,34}. Wilson *et al.* found that robotic lung resection including lobectomy was associated with a higher nodal upstaging rate³⁴. However, in line with our findings, Hennon and colleagues reported that RAL and VAL had a similar rate of nodal upstaging³². Accordingly, a final conclusion has yet to be reached, and further study is needed.

In terms of perioperative outcomes, RAL was associated with a small but statistically lower intraoperative blood loss compared with VAL, which might be related to the improved flexibility and operability of the robotic surgical system. Mahieu *et al.*⁸ also believed that RAL could reduce the incidence of severe intraoperative bleeding. However, in our study,

both RAL and VAL achieved excellent bleeding control, and no difference was observed between the two groups in the conversion rate to thoracotomy or the rate of intraoperative blood transfusion. Likewise, the difference in blood loss, although statistically significant, was low. For these reasons, both approaches appear to be safe regarding bleeding control, and the clinical significance of any reduced blood loss after RAL may be minor. However, due to the improved bleeding control as previously reported^{8,23}, and the statistically reduced blood loss as observed in our trial, bleeding control may indeed be considered a potential advantage of RAL compared with the VAL.

Despite having less intraoperative blood loss, the RAL group had a larger amount of postoperative chest drainage (830 ml [IQR, 550-1130 ml] vs. 685 ml [IQR, 367.5-1160 ml], $P=0.007$). Few studies have addressed the difference in chest drainage between robotic and video-assisted pulmonary surgery. According to our experience, RAL was associated with more extensive LN evaluation, which may have resulted in damage to the bronchial arteries, veins, and lymphatic vessels connected with the LNs during resection and therefore, might have led to the increase in postoperative chest drainage. Also, a harmonic scalpel (Harmonic Focus; Ethicon, Johnson and Johnson, Cincinnati, OH, USA) was regularly used for nodal dissection during VAL, while monopolar electrocautery was used in RAL. The difference in the energy devices employed may also have had an impact on the amount of postoperative drainage³⁶. Another potential explanation is that the pleural effusion caused by surgical trauma was increased. In the RAL group, five ports were routinely placed, whereas for VAL only one or two were placed. Despite the significantly higher total amount of postoperative chest tube drainage after RAL, the chest tube duration after surgery ($P=0.97$) and the

postoperative hospital stay ($P=0.76$) were comparable between both groups. The higher chest tube output did not delay chest tube removal and patient discharge.

According to previous studies, operative time is commonly reported to be longer in robotic surgery^{10,37}, which may be attributed to the additional docking time and the impact of a learning curve. In this study, the operative time was not different between the groups, and RAL was even associated with a slightly shorter mean operative time of 10 minutes. This reduction of RAL time may be attributed to accumulation of surgical experience, a dedicated robotic team, and a high-volume center.

Regarding hospitalization expenses, the total cost and indirect cost associated with RAL in this study were significantly higher than those with VAL. However, the direct cost was comparable between RAL and VAL. This may be due to the higher costs of supplies and depreciation for the robotic system. A meta-analysis involving 12 RAL-related studies also suggested that it was reasonable to consider the cost performance index when selecting RAL for NSCLC, due to its relatively high cost³⁸.

This study has several limitations. Firstly, the single-center nature of this clinical trial makes it less persuasive than a multicenter study. Secondly, it only reports on the short-term perioperative results. Further ongoing follow-up will eventually clarify any difference in long-term survival between robotic and video-assisted lobectomy. Furthermore, the da Vinci S/Si robot was routinely used for RAL while a uniportal approach was employed for VAL. Further investigation would be needed to determine if our results are generalizable to other centers where other robotic systems or multiport thoracoscopy may be more common.

In conclusion, this was the first prospective RCT to compare RAL with VAL for the treatment of NSCLC. Both the robotic- and video-assisted techniques were demonstrated to be safe and feasible. RAL was associated with a higher number of LNs dissected; however, it also resulted in an increased amount of chest drainage and higher hospitalization costs. Further follow-up is ongoing to evaluate and compare the long-term efficacy of RAL and VAL.

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Figure Legends

Figure 1. Study enrollment. Abbreviations: RAL, robotic-assisted lobectomy; VAL, video-assisted lobectomy.

Figure 2. (A) Trocar insertion points for robotic-assisted lobectomy (RAL). (B) Typical incision for video-assisted lobectomy (VAL), covered with protective sleeve.

Figure 3. Subgroup analyses for impact of surgical technique on total number of dissected lymph nodes. Abbreviations: AIS, adenocarcinoma *in situ*; BMI, body mass index; CI, confidence interval; ECOG PS, Eastern Cooperative Oncology Group performance score; IQR, interquartile range; MIA, minimally invasive adenocarcinoma; RAL, robotic-assisted lobectomy; VAL, video-assisted lobectomy.

Table 1. Patient pathological outcomes

Characteristic	Robotic-assisted lobectomy (n=157)	Video-assisted lobectomy (n=163)	<i>P</i>
			0.7
Histology, No. (%)			9
AIS or MIA	19 (12.1)	16 (9.8)	
Adenocarcinoma	124 (79.0)	128 (78.5)	
Squamous cell carcinoma	12 (7.6)	17 (10.4)	
Large cell carcinoma	2 (1.3)	2 (1.2)	
Number of malignant lesions, No. (%)			0.9
			3
1	142 (90.4)	151 (92.6)	
2	11 (7.0)	8 (4.9)	
3	2 (1.3)	2 (1.2)	
4	2 (1.3)	2 (1.2)	
			0.8
Pathological T stage, No. (%)			7
pTis	2 (1.3)	1 (0.6)	
pT1a(mi)	17 (10.8)	14 (8.6)	
pT1a	24 (15.3)	25 (15.3)	
pT1b	69 (43.9)	64 (39.3)	
pT1c	18 (11.5)	25 (15.3)	
pT2a	21 (13.4)	22 (13.5)	
pT2b	3 (1.9)	7 (4.3)	
pT3	1 (0.6)	2 (1.2)	
pT4	2 (1.3)	3 (1.8)	
			0.6
Pathological N stage, No. (%)			6
pN0	141 (89.8)	141 (86.5)	

pN1	6 (3.8)	8 (4.9)	
pN2	10 (6.4)	14 (8.6)	
			0.8
Pathological TNM stage, No. (%)			9
0	2 (1.3)	1 (0.6)	
IA1	40 (25.5)	39 (23.9)	
IA2	67 (42.7)	59 (36.2)	
IA3	15 (9.6)	20 (12.3)	
IB	12 (7.6)	13 (8.0)	
IIA	3 (1.9)	6 (3.7)	
IIB	7 (4.5)	9 (5.5)	
IIIA	10 (6.4)	14 (8.6)	
IIIB	1 (0.6)	2 (1.2)	

Abbreviations: AIS, adenocarcinoma in situ; MIA, minimally invasive adenocarcinoma.

Table 2. Perioperative outcomes

Characteristic	Robotic-assisted lobectomy (n=157)	Video-assisted lobectomy (n=163)	<i>P</i>
Operation time [min], median (IQR)	110 (95-140)	120 (97.5-150)	0.25
Blood loss [ml], median (IQR)	100 (50-100)	100 (50-150)	0.04
Intraoperative blood transfusion, No. (%)	3 (1.9)	2 (1.2)	0.68
Postoperative hospital stay [days], median (IQR)	4 (4-5)	5 (4-5)	0.76
Chest tube duration [days], median (IQR)	3 (2-4)	3 (2-4)	0.97
Conversion to thoracotomy, No. (%)	7 (4.5)	9 (5.5)	0.86
Chest tube drainage [ml], median (IQR)	830 (550-1130)	685 (367.5-1160)	0.007
Postoperative complications, No. (%)	23 (14.6)	30 (18.4)	0.45
Clavien Dindo I-II	18 (11.5)	24 (14.7)	0.49
Pleural effusion	8 (5.1)	12 (7.4)	0.54
Pneumonia	4 (2.5)	1 (0.6)	0.21
Prolonged air leak	9 (5.7)	7 (4.3)	0.74
Recurrent air leak	0	1 (0.6)	>0.9
Hemorrhage	1 (0.6)	1 (0.6)	>0.9
Atrial fibrillation	0	1 (0.6)	>0.9
Ischemic stroke	0	1 (0.6)	>0.9
Hypoxemia	0	1 (0.6)	>0.9

			9
			>0.9
Clavien Dindo III-IV	5 (3.2)	6 (3.7)	9
			>0.9
Pleural effusion	2 (1.3)	2 (1.2)	9
			>0.9
Pneumonia	0	1 (0.6)	9
Prolonged air leak	0	3 (1.8)	0.25
			>0.9
Recurrent air leak	1 (0.6)	1 (0.6)	9
			>0.9
Hemorrhage	1 (0.6)	1 (0.6)	9
Ischemic stroke	2 (1.3)	0	0.24
Hospitalization cost [\$], median (IQR)	12821 (12145-13924)	8009 (7014-9003)	<0.0 01
			<0.0 01
Indirect cost [\$], median (IQR)	5197 (5197-5205)	453 (445-453)	0.15
Direct cost [\$], median (IQR)	7624 (6491-8708)	7572 (6574-8550)	
Visual analogue scale			
Postoperative day 1, median (IQR)	2 (2-3)	3 (2-3)	0.08
Postoperative day 2, median (IQR)	2 (2-3)	2 (2-3)	0.13
Postoperative day 3, median (IQR)	2 (2-2)	2 (2-3)	0.60
Duration of extra analgetic [days], median (IQR)	0 (0-1)	0 (0-1)	0.11
			>0.9
Readmission, No. (%)	3 (1.9)	3 (1.8)	9

Abbreviations: IQR, interquartile range.

Table 3. Lymph node dissection

Characteristic	Robotic-assisted lobectomy (n=157)	Video-assisted lobectomy (n=163)	<i>P</i>
Total number of lymph nodes, median (IQR)	11 (8-15)	10 (8-13)	0.02
Total number of lymph node stations, median (IQR)	6 (5-7)	5 (4-6)	<0.001
Number of N1 lymph nodes, median (IQR)	6 (4-8)	5 (3-7)	0.005
Number of N2 lymph nodes, median (IQR)	5 (4-8)	5 (3-7)	0.19
Nodal upstaging, No. (%)	12 (7.6)	20 (12.3)	0.23
Upstage, No. (%)			
cN0 to pN1	4 (2.5)	8 (4.9)	0.41
cN0 to pN2	6 (3.8)	7 (4.3)	>0.99
cN1 to pN2	2 (1.3)	5 (3.1)	0.45

Abbreviations: IQR, interquartile range.